IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Robert Lewis, et al.
Serial No.:	10/537,215
Filing Date:	December 4, 2003
Art Unit:	3721
Examiner:	Unknown
Confirmation No.:	4676
Title:	AUTOMATED RIVETING MACHINE

Office of Initial Patent Examination's Customer Service Center
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

SECOND REQUEST FOR CORRECTED OFFICIAL FILING RECEIPT

Attached is a copy of the Official Filing Receipt received from the U.S. Patent and Trademark Office ("USPTO") in the above-identified patent application for which issuance of a corrected filing receipt is respectfully requested.

At Total Claims, please delete "40" and insert **-- 31 --.**

REMARKS

The above-identified national stage patent application was filed via Express Mail with the U.S. Patent and Trademark Office on June 3, 2005 (copy of Certificate of Express Mail attached). At the time the application was filed a substitute specification was filed as indicated in the transmittal letter. *See Item 15 on the attached copy of Transmittal Letter to the United States Designated/Elected Office (DO/EO/US) Concerning a Filing Under 35 U.S.C. 371.* The substitute specification amended the claims from International Application No. PCT/GB2003/005308 from forty (40) to thirty-one (31). The substitute specification was received by the USPTO as indicated by the attached copy of the date-stamped returned acknowledgement postcard. However, in a check of the Patent Application Information Retrieval ("PAIR") website, it was discovered that the substitute specification has not been made part of the record of this patent application.

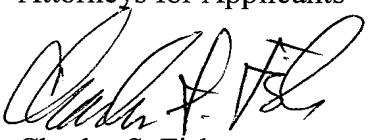
Applicant hereby requests that the attached copy of the substitute specification be entered and that a corrected filing receipt be issued.

While it is believed that this is not an error by the Applicants, the Commissioner is hereby authorized to charge any amount required by this paper or credit any overpayment to Deposit Account No. 02-0384 of Baker Botts L.L.P.

Respectfully submitted this 21st day of September, 2006.

BAKER BOTTS L.L.P.

Attorneys for Applicants



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Attachments:

Copy of Official Filing Receipt (corrected), dated September 12, 2006.
Copy of Transmittal Letter to the United States Designated/Elected Office (DO/EO/US) Concerning a Filing Under 35 U.S.C. 371, dated June 3, 2005 (2 pages).
Copy of substitute specification, entitled "Automated Riveting Machine" (25 pages).
Copy of return acknowledgment postcard, dated June 3, 2005.
Copy of Certificate of Mailing by Express Mail, dated June 3, 2005.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
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APPL NO.	FILING OR 371 (c) DATE	ART UNIT	FIL FEE REC'D	ATTY.DOCKET NO	DRAWINGS	TOT CLMS	IND CLMS
10/537,215	03/09/2006	3721	1980	072819.0177	7	~~40~~ 31	4

CONFIRMATION NO. 4676

CORRECTED FILING RECEIPT

OC000000020397038

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BAKER BOTTS L.L.P.
2001 ROSS AVENUE
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DALLAS, TX 75201-2980

Date Mailed: 09/12/2006

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please mail to the Commissioner for Patents P.O. Box 1450 Alexandria Va 22313-1450. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections (if appropriate).**

Applicant(s)

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Power of Attorney: The patent practitioners associated with Customer Number **5073**.

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/GB03/05308 12/04/2003

Foreign Applications

UNITED KINGDOM 0228259.8 12/04/2002
If Required, Foreign Filing License Granted: 06/28/2006

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is US10/537,215

Projected Publication Date: 10/05/2006

Non-Publication Request: No

Early Publication Request: No

Title

Automated riveting machine

Preliminary Class

227

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

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Title 35, United States Code, Section 184
Title 37, Code of Federal Regulations, 5.11 & 5.15

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PTO-1390 (Rev. 02-2005)
Approved for use through 3/31/2007. OMB 0651-0021
U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	
072819.0177	
U.S. APPLICATION NO. (If known, see 37 CFR 1.5) N/A	

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB2003/005308	12/04/2003	12/04/2002

TITLE OF INVENTION
AUTOMATED RIVETING MACHINE

APPLICANT(S) FOR DO/EO/US
Michael Gribben, et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)) EV473951189US
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☒ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendment has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).**Unsigned**
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ An information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A preliminary amendment.
14. ☐ An Application Data Sheet under 37 CFR 1.76.
15. ☒ A substitute specification.
16. ☒ A power of attorney and/or change of address letter. **Unsigned**
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.2 and 37 CFR 1.821-1.825.
18. ☒ A second copy of the published International Application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items of information. Certificate of Express Mail; Acknowledgement Postcard; PCT Request (Form PCT/RO/101); Drawing Sheets (7 pages); International Search Report

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
N/A	PCT/GB2003/005308	072819.0177

The following fees are submitted:	CALCULATIONS	PTO USE ONLY
21. ☒ Basic national fee: $300	$300.00	
22. ☒ Examination fee If International preliminary examination report prepared by USPTO and all claims satisfy provisions of PCT Article 33(1)-(4) ..... $100 All other situations $200	$200.00	
23. ☒ Search fee Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority ..... $100 International Search Report prepared and provided to the Office ..... $400 All other situations $500	$400.00	
TOTAL OF 21, 22 and 23 =	$900.00	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is **$250** for each additional 50 sheets of paper or fraction thereof.		
Total Sheets: - 100 = / Extra Sheets: /50 = / Number of each additional 50 or fraction thereof (round up to a whole number): / RATE: x **$250**	$	
Surcharge of **$130.00** for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h)).	$	

CLAIMS	NUMBER FIELD	NUMBER EXTRA	RATE		
Total claims	31- 20 =	11	x	**$50**	$550.00
Independent claims	5- 3 =	2	x	**$200**	$400.00
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+	**$360**	$

TOTAL OF ABOVE CALCULATIONS =	$950.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by ½.		
SUBTOTAL =	$1850.00	
Processing fee of **$130.00** for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)). +	$	
TOTAL NATIONAL FEE =	$1850.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +	$	
TOTAL FEES ENCLOSED =	$1,850.00	
Amount to be refunded:	$	
Amount to be charged:	$	

a. ☒ A check in the amount of $ 1850.00 to cover the above fees is enclosed.

b. ☐ Please charge by Deposit Account No. _____ in the amount of $ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

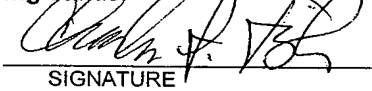
c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-0384. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limited under 37 CFR 1.494 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.

SEND ALL CORRESPONDENCE TO:

CUSTOMER NO. **05073**


SIGNATURE

Charles S. Fish
NAME:

35,870
REGISTRATION NUMBER:

FORM PTO-1390 (REV. 02-2005)

AUTOMATED RIVETING MACHINE

TECHNICAL FIELD OF THE INVENTION

This invention relates to improvements in automated riveting machines. In particular, to those machines in which an end-effector is configured to achieve a rivet connection in a workpiece, to a method of achieving a rivet connection, and to a tool support adapted for use in an end-effector in an automated riveting machine.

BACKGROUND OF THE INVENTION

An end-effector is a device or tool which is connected to a robot. The structure of the end-effector depends upon the task to be performed.

Riveting machines are capable of performing all the processes necessary for automated riveting of aero-structures. However, the machines are large, expensive and relatively inflexible. There are also limits to the percentage of the total rivets that can be inserted automatically, the remaining requiring manual insertion. These limits are due either to access limitations or rivet type. The high capital cost and long lead times of these machines can cause capacity bottlenecks and result in a requirement for significant manual riveting. The use of excessive manual riveting also has health and safety implications.

We are aware of US 5375754 which discloses a robot mounted automated riveting machine including a drilling unit with lubricator, and a riveting unit, comprising a rivet supply unit and a squeezing rivet setter. The drilling unit and rivet setter being movable along a support console.

US 5379508, US 4996761, US 5231747 and US 5611130 disclose devices with the capacity to drill and rivet a workpiece, in which the drill and rivet tools are independently brought to the workpiece requiring accurate tool placement.

US 5404633 discloses a drill quill which is coaxially mounted within a rivet driver. US 4762261 discloses a computer aided riveting robot. US 5458443 discloses a system that permits positioning

of a drill bit in difficult locations allowing overhead and sideways drilling in addition to normal downward drilling. US 5586391 discloses a method of drilling co-ordination holes in components using an end-effector carried by a precision computer controlled robot. US 5037020 discloses a drilling and riveting tool including a 'C' shaped support frame.

SUMMARY OF THE INVENTION

According to this invention an end-effector for an automated riveting machine includes a drill tool, a sealant dispensing tool and a riveting tool.

Alternatively, the end-effector of the invention may comprise at least two tools, wherein at least one of the tools is a riveting tool. The other tool, or tools, being any other suitable tool, for example, a drill, an adhesive, sealant or lubricant dispensing/applying tool, a screw driver, a screw applying tool, a nut or bolt applying tool, or a self piercing riveting device.

The end-effector may be provided with a fixed datum with respect to which the tools are movable.

The fixed datum may be configured as a guide hole. The individual tools of the end-effector may operate through the guide hole, ensuring accuracy of tool placement at a workpiece.

Preferably the end-effector includes a tool support, configured to accommodate the tools, in which the fixed datum or guide hole is located. Preferably the guide hole is located at the end of the tool support which in use is located closest to the workpiece. When the end-effector is in use the guide hole may contact the workpiece.

The use of a fixed datum within the end-effector removes the requirement for high levels of repeatability from the positioning system within the end-effector and from the positioning robot since it remains stationary throughout the riveting cycle. This approach results in a significant reduction in size, cost and complexity relative to existing

systems where the individual units are positioned independently.

Preferably individual tools are movable in the end-effector between a resting position, spaced away from the guide hole, and an operating position, at the guide hole, from where each individual tool can perform its designed operation.

The tool support of the end-effector may include at least one carrier arm in which at least one tool may be accommodated. Preferably an end-effector with three tools, such as a drill, a sealant dispenser and a riveting tool, includes three carrier arms, each accommodating one of the three tools.

Preferably the carrier arm is movable relative to the guide hole or fixed datum. In an end-effector with more than one carrier arm, one or more of the carrier arms may be movable.

Preferably movement of the carrier arm will also effect movement of a tool accommodated therein. By moving the carrier arm the tool may be moved from the resting position to the operating position, or from the operating position to the resting position, or to any position there between.

A carrier arm may include one or more bores. The bores may be used to mount a carrier arm on a support member of the tool support or to accommodate a tool. Preferably, each carrier arm comprises two bores, the first bore may be used to mount the carrier arm on a support member, and the second bore may accommodate a tool.

Preferably one carrier arm is mounted on one support member, however more than one carrier arm may be mounted on one support member.

Preferably the support members, upon which carrier arms may be mounted, form part of the tool support. The support members may be configured as rigid structures. There may be more than one support member. Preferably the end-effector includes three parallel support members. The support members may fix opposing ends of the tool support of the end-effector in a fixed spaced relationship. Opposing ends of the tool support may be configured as plates. The end of the tool support which in use is located closest to the workpiece may include the guide hole or fixed datum. The guide hole may be included in an end plate. Preferably the support members are spaced around the guide hole. The support members may be located equidistant from the guide hole and equidistant from each other.

A carrier arm mounted on a support member may pivot about the support member. In an end-effector with more than one carrier arm one or more of the arms may pivot. The pivoting of a carrier arm accommodating a tool may move the tool between the resting and the operating position. That is, the tool may be moved from a resting position to the side of the guide hole to an operating position over the guide hole and back again. The pivoting of the carrier arm may result in the arcuate movement of a tool accommodated therein. Preferably a ram and cylinder assembly moves each carrier arm, this may be pneumatically operated.

Preferably, an end-effector with three tools, has three carrier arms, each accommodating a different tool, each carrier arm mounted on one of three different support members. Each carrier arm may pivot about the support member on which it is mounted to bring each tool to the guide hole in turn. Preferably each carrier arm moves in the same plane. Once a tool is located at the guide hole it may operate through the guide hole to perform its designed function.

By way of example, if a drilling tool, a sealant dispensing tool and a riveting tool are located in three carrier arms each may be sequentially positioned at the guide hole, in the operating position. Firstly, the drill may be moved to the operating position, where drilling and countersinking operations may be performed in the workpiece. Secondly, the drilling tool may be moved to a resting position and the sealant dispensing tool may be moved into the operation position where it may dispense sealant. Finally, the sealant dispensing tool may be moved to a resting position, and the riveting tool may be brought to the operating position where it may insert a rivet into the drilled hole, and then deform the rivet stem and head to complete the riveting process.

A tool support of the end-effector may also comprise a feed mechanism. Preferably the feed mechanism is adapted to extend a tool, in the operating position, into the guide hole. Once a tool is located in the guide hole it may be operated to perform its designed function. The feed mechanism

may be further adapted to retract the tool from the guide hole. The feed mechanism may be adapted to capture a tool, for example, by using a movable plate adapted to capture the end of the tool distal to the guide hole. The feed mechanism may move a tool using one or more ram and cylinder assemblies. The plate may be suspended from one or more ram and cylinder assemblies, the cylinder and ram assemblies may operate to move the plate and the captured tool. Preferably the plate is configured such that when it is moved it can pass the support members and any tools located in a resting position.

Preferably the end-effector includes a load cell, such as a piezo-ceramic cell, which may be located at the interface between the end-effector and the robot arm. The load cell allows the force applied by the end-effector to be accurately controlled.

Preferably the end-effector is compact comprising a cylinder of 200 mm in diameter, 400 mm in height, and an estimated weight of 40 Kg. The compact nature of the end-effector allows riveting to be performed in confined areas, thus increasing the number of rivets that can be inserted automatically.

It is envisaged that the end-effector will be able to operate with a cycle time of less than 5 seconds per rivet - allowing for time spent loading workpieces and positioning the robot. This compares with up to 20 seconds for traditional automated riveting machines.

According to a second aspect of the invention an automated riveting machine comprises a first end-effector carrying the tools, and a second end-

effector, the second end-effector being positioned on the opposite side of the workpiece to, and in-line with, the first end-effector.

The first end-effector may be in accordance with the first aspect of the invention.

Preferably the second end-effector comprises a clamping foot for clamping the workpiece, and/or a moveable reactor for upsetting a rivet stem.

The second end-effector may be slaved to, or synchronised with, the first end-effector, its location being determined by the location of the first end-effector.

According to a third aspect of the invention a method of achieving a rivet connection in a workpiece comprises locating a first end-effector, with at least two tools one of which is a riveting tool, at a workpiece and positioning a second end-effector at the opposite side of the workpiece in-line with the first end-effector; sequentially moving each tool, in the first end-effector, from a resting position to an operating position above a guide hole in a lower end plate of the first end-effector, and operating each tool in turn through the guide hole to perform their desired operation.

Preferably an additional tool is configured as a sealant dispensing tool and/or a drill tool.

According to a fourth aspect of the invention a tool support, adapted in use to define an end-effector of an automated riveting machine, comprises at least two tool carrier arms, one of which is adapted to support a riveting tool, in which the tool

carrier arms are movable relative to a fixed datum defined by the tool support.

Preferably the fixed datum is configured as a guide hole in the tool support. Preferably the guide hole is located at the end of the tool support which in use is located closest to the workpiece, and may contact the workpiece in use.

Preferably the tool support is configured as a cage structure, in which rigid support members hold opposing ends of the tool support in a fixed spaced relationship. Preferably the support members are parallel. There may be one or more support members. There may be three support members. The support members may be spaced around the guide hole, preferably equidistant therefrom and/or from one another. Preferably the support members are located equidistant from one another. The opposing ends of the tool structure may be configured as end plates. The end plate located nearest the workpiece in use may incorporate the guide hole.

Each carrier arm of the tool support may include one or more bores. The bores may be used to mount the carrier arm on a support member or to accommodate one or more tools. Preferably each tool carrier arm is configured with two bores, the first bore being used to mount the carrier on a rigid support member, the second bore accommodating a tool. Movement of the carrier arm may allow the second bore to be positioned over the guide hole. The carrier arm may move by pivoting about the support member.

Each carrier arm may be mounted on different support members, or more than one carrier arm may be

mounted on one support member. One or more carrier arms may pivot about the support member upon which it is mounted.

Preferably moving the carrier arm will move any tool accommodated in the second bore. Pivoting the carrier arm about the support arm may effect movement of a tool located in the carrier arm second bore between the resting position and the operating position. The operating position being when the second bore, which may contain a tool, is located over the guide hole.

Preferably the carrier arm is moveable by a ram and cylinder assembly. The ram and cylinder may be pneumatically operated.

A tool support of the end-effector may also comprise a feed mechanism. Preferably the feed mechanism is adapted to extend a tool, in the operating position, into the guide hole. Once a tool is located in the guide hole it may be operated to perform its designed function. The feed mechanism may be further adapted to retract the tool from the guide hole. The feed mechanism may be adapted to capture a tool, for example, by using a movable plate adapted to capture the end of the tool distal to the guide hole. The feed mechanism may move a tool using one or more ram and cylinder assemblies. The plate may be suspended from one or more ram and cylinder assemblies, the cylinder and ram assemblies may operate to move the plate and the captured tool. Preferably the plate is configured such that when it is moved is can pass the support members and any tools located in a resting position.

This nature of the design of the tool support makes it easy to use alternative tools without having to change the end-effector design.

BRIEF DESCRIPTION OF THE DRAWINGS

There will now be described, by way of example only, one embodiment of the present invention with reference to the accompanying drawings of which:

Figure 1 is a schematic perspective view of the automated riveting machine, comprising an upper and a lower end-effector located at a workpiece;

Figure 2 is a schematic perspective view of the upper end-effector of Figure 1;

Figure 3 is a schematic perspective view of the cage structure assembly of the end-effector of Figure 2, in which the guide hole is clearly visible;

Figure 4 is a schematic perspective view of the feed-mechanism assembly of the end-effector of Figure 2;

Figure 5 is a schematic perspective view of a drill tool which could be used with the end-effector of Figure 2;

Figure 6 is a schematic perspective view of a riveting tool which could be used with the end-effector of Figure 2;

Figure 7 is a view of the lower end-effector or 'bucking bar' of Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

One embodiment of an automated riveting machine according to the present invention is illustrated in Figure 1 of the accompanying drawings. The machine comprises two end-effectors, an upper end-effector 11 and a lower end-effector 12, mounted upon robots 18, located at workstations on opposite sides of a workpiece 14. The workpiece 14 comprises two pieces 15 and 16 which are to be riveted together.

The end-effectors 11 and 12 are both lightweight and are carried on separate, compact robots 18, such as the NEOS Tricept™ robot, however any suitable robot could be used.

In this embodiment, the upper end-effector 11 functions as a drilling, sealant dispensing and riveting tool, and is described in more detail with reference to Figures 2 to 6 of the accompanying drawings. The lower end-effector 12, described in more detail in Figure 7, is positioned behind the workpiece 14, in line with the upper end-effector 11, and provides clamping during drilling and counter sinking operations and acts as 'bucking bar' during the rivet upsetting operation. The opposing forces applied by each end-effector helps to hold the end-effector in position.

Figures 2 to 6 show details of the upper end-effector assembly 20.

The upper end-effector 20 comprises three tools, a drilling tool (not visible in this view), a sealant dispensing tool (also not visible in this view), and a riveting tool 22. Each tool is used sequentially to rivet a workpiece. Initially a hole is drilled in

the workpiece, sealant is then placed into the hole to ensure that the rivet connection will be airtight, allowing the structure to be pressurised, and finally a rivet is placed in the hole and the stem upset to fix the rivet in place.

Each tool is located in a carrier arm. Although only two carrier arms 23 and 24 are visible in the view in Figure 2 three arms are present, each carrying a respective one of the three tools. Carrier arm 23 is depicted with the riveting tool 22 located therein. Each carrier arm has two bores 26 and 27. Bore 26 allows the carrier arm 23 to be located on a cage structure support member 39 (Figure 2) of the upper end-effector 20. The other bore 27 accommodates the tool, in this case the riveting tool 22.

Figure 3 is a schematic perspective view of the cage structure 30 of the upper end-effector 20. The cage structure 30 is a rigid frame comprising an upper end plate 32 and a lower end plate 33 held in a fixed spaced relationship by three cylindrical support members 37, 38 and 39. In the complete upper end-effector 20 (depicted in Figure 2), the tool carrier arms 23 and 24 are mounted upon, and can pivot about, the support members 37, 38 and 39.

The support members 37, 38 and 39 are radially spaced around a datum point comprising a central guide hole 40 in the lower end plate 33. The guide hole 40 serves as a fixed datum within the upper end-effector 20 in which each working head or tool can be sequentially placed and operated. This removes the need for high levels of repeatability in tool

positioning and alignment from the robot 18 once the upper end-effector 20 has been positioned at the workpiece.

Once the upper end-effector 20 is positioned at the workpiece, the drilling, sealing and riveting functions are all performed without moving the upper end-effector 20, each tool operating in turn though the fixed datum guide hole 40. Each tool is located in a carrier arm 23, 24, which is pivoted about its respective support 39, 37 to locate the tool above the guide hole 40 as needed.

The pivoting of the carrier arms 23, 24 is facilitated by pneumatic cylinders and rams. For example, carrier arm 24 is pivoted about support 37 by expansion and retraction of the ram in pneumatic cylinder 44, which is fixed to the end plate 33 at one end and to the carrier arm 24 at the other. In the retracted position the tool is located in a resting position, toward the outer edge of lower end plate 33, and in the extended position, the operating position, the tool is located above the guide hole 40.

Once a tool 22 is located above the guide hole 40 the feed mechanism, illustrated in Figure 4, operates to move the tool 22 towards the workpiece.

The feed mechanism comprises a plate 57 suspended from which are three 52, 53 and 54 pneumatic cylinders and rams, which operate to lower and raise the plate 57. In the complete upper end-effector 20 illustrated in Figure 2 the pneumatic rams and cylinders 53, 54 are shown connected to the lower end plate 33. The plate 57 is shaped with cut out

portions 62, 63, and 64 configured to locate around and move past the support members 37, 38 and 39 of the cage structure 30. Further cut out portions 66, 67 and 68 in plate 57 are configured to locate around and move past tools in the resting position. When a tool is located above the guide hole 40 (not illustrated) ready for use, the pneumatic cylinders 52, 53 and 54 will be operated to retract the ram and lower the plate 57. The central hole 71 of the plate 57 contacts and captures the tool 22, about a projection 35 on the uppermost end, and depresses it somewhat towards the workpiece. The extent of movement of the tool towards the workpiece depends on the nature of the tool and the function it has to perform.

Each tool is self-contained, requiring only services and control signals from the upper end-effector. The tools can be readily removed for maintenance, repair or exchange, say, to accommodate different types or sizes of fastener.

Figure 5 illustrates a tool configured as a drill 82, which can be located in the bore of any carrier arm, such as 23 or 24. The drill unit is controlled by an internal drive, and is not driven by the robot 18.

Exhaust from the air motor of the drill is diverted to immediately remove the swarf produced by drilling, eliminating the need for a separate air feed specifically for this function.

Figure 6 illustrates a tool configured as a riveting tool 92. Again this tool an be located in any carrier arm. Rivets 93 are gripped by jaws 94

and placed in a drilled hole in the work piece. The jaws 94 are then opened to release the rivet 93. Once in position a vibration using pneumatics is applied to upset the rivet against the lower end-effector 12 or bucking bar located on the other side of the workpiece (Figure 1).

The upper-end-effector 20 also contains an advanced monitoring system to allow instant detection of any process failures before damage occurs to the workpiece and to maintain overall machine quality control. Indeed, camera inspection of the process allows hole quality, the drill end and rivet placement to be monitored. The camera may be located in the sealant dispensing tool. Each rivet can be checked for quality and a process conformity report supplied. Sensors can be positioned at all steps and if set criteria are not met the machine will stop.

A load cell 101, 100 is located at the interface between the upper end-effector 11, 20 and the robot 18 (Figures 1 and 2). The load cell is a pressure-monitoring device comprising a piezo-ceramic cell which monitors and controls pressure exerted upon it. The load cell effects the movement of the upper end-effector 11 and the lower end-effector 12 towards or away from the workpiece 14 as necessary. The load required depending upon the stage of the riveting cycle. For example, when drilling a higher force is required to minimise burring and the upper and lower end-effectors essentially clamp the workpiece. When a rivet is inserted into the drilled hole the force is relaxed.

Figure 7 illustrates the lower end-effector 110 which is considerably simpler than the upper-end-effector 20 (Figure 2), having a clamping foot 112 and moveable reactor 114 for upsetting the rivet stem. The main purpose of the lower end-effector 110 is to provide a reactive force for the upper end-effector 20 situated on the opposite side of the workpiece 14.

The geometry of the clamp foot is designed to accommodate the maximum possible number of frame/stringer geometries. There may be occasions however, where lower end-effectors with 'special to type' geometries will be required.

Ideally, the control system for the automatic riveting machine uses an industrial PC, which supports both the control of the end-effectors and communication with the robot. Indeed the lower end-effector robot may be slaved to the upper end-effector robot, such that the lower end-effector automatically moves in response to movement of the upper end-effector.

Whilst in the above embodiment tools configured as a drill, sealant dispenser and riveter have been considered, in practice any suitable tool or the working head could be any tool, such as a screwdriver or a self piercing riveting device, depending on the intended task to be performed.

WHAT IS CLAIMED IS:

1. A tool support, adapted in use to define an end-effector of an automated riveting machine, comprising at least two tool carrier arms, one of which is adapted to support a riveting tool, in which the tool carrier arms are movable relative to a fixed datum defined by the tool support.

2. A tool support as claimed in claim 1 in which the fixed datum is configured as a guide hole.

3. A tool support as claimed in claim 1 in which one or more support members hold opposing ends of the tool support in a fixed spaced relationship.

4. A tool support as claimed in claim 3 in which opposing ends of the tool support are configured as end plates.

5. A tool support as claimed in claim 4 in which the guide hole is located in the end plate which is positioned closest to a workpiece when in use.

6. A tool support as claimed in claim 3 in which the support members are spaced around the guide hole.

7. A tool support as claimed in claim 1 in which the carrier arm includes one or more bores.

8. A tool support as claimed in claim 7 in which a first bore in the carrier is used to mount the carrier arm on a support member, and a second bore in the carrier arm may accommodate a tool.

9. A tool support as claimed in claim 8 in which the carrier arm is movable to locate the second bore over the guide hole.

10. A tool support as claimed in claim 7 in which the carrier arm can pivot about the support member upon which it is mounted.

11. A tool support as claimed in claim 1 including a feed mechanism adapted to extend and retract a tool, accommodated in a carrier arm, into and out of the guide hole.

12. A tool support as claimed in claim 11 in which the feed mechanism comprises a plate suspended from a cylinder and ram assembly adapted to raise and lower the plate.

13. A tool support as claimed in claim 11 in which the feed mechanism is adapted to capture a tool accommodated in a carrier arm.

14. An end-effector for an automated riveting machine comprising a drilling tool, a sealant dispensing tool and a riveting tool.

15. An end-effector as claimed in claim 14 provided with a fixed datum with respect to which the tools are movable.

16. An end-effector as claimed in claim 15 in which the fixed datum is configured as a guide hole.

17. An end-effector as claimed in claim 16 in which the tools are configured to operate through the guide hole

18. An end-effector as claimed in claim 16 in which the guide hole is located in the end of the end-effector which in use is positioned closest to a workpiece.

19. An end-effector as claimed in any of claims 14 in which the tools are movable between a resting position and an operating position.

20. An end-effector as claimed in claim 14 in which a tool is accommodated in a movable carrier arm.

21. An end-effector as claimed in claim 14 which includes three movable carrier arms, each carrier arm accommodating one tool.

22. An end-effector as claimed in claim 20 in which the carrier arm is mounted on a support member.

23. An end-effector as claimed in claim 22 in which the carrier arm can pivot about the support member upon which it is mounted.

24. An end-effector as claimed in claim 20 in which a carrier arm includes one or more bores.

25. An end-effector as claimed in claim 24 in which a first bore is used to mount the carrier arm on the support member and a second bore may accommodate a tool.

26. An end-effector as claimed in claim 16 which includes a feed mechanism adapted to extend a tool into, and/or retract a tool from, the guide hole.

27. An end-effector as claimed in claim 14 including a load cell.

28. An automated riveting machine comprising a first end-effector and a second end-effector, the first end-effector carrying the tools, the second end-effector being positioned on the opposite side of a workpiece to, and in-line with, the first end-effector.

29. A machine as claimed in claim 28 in which the second end-effector comprises a clamping foot for clamping the workpiece.

30. A machine as claimed in claim 28 which the second end-effector comprises a moveable reactor for upsetting a rivet stem.

31. A method of achieving a rivet connection in a workpiece comprising:

locating a first end-effector, with at least two tools one of which is a riveting tool, at a workpiece;

positioning a second end-effector at the opposite side of the workpiece in-line with the first end-effector;

sequentially moving each tool, in the first end-effector, arcuately from a resting position to an operating position above a guide hole in a lower end plate of the first end-effector; and

operating each tool in turn through the guide hole to perform their desired operation.

AUTOMATED RIVETING MACHINE

ABSTRACT OF THE DISCLOSURE

A tool support adapted in use to define an end effector of an automated riveting machine, comprising at least two carrier arms one of which is adapted to support a riveting tool, in which the tool carrier arms are movable relative to a fixed datum defined by the tool support.

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